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STABILITY OF NONCONSERVATIVE SYSTEMS

submitted by

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During the period covered by the present progress report the manuscripts of two analytical studies, which were completed earlier were submitted for publication in the Journal of Applied Mechanics. The first report is entitled "On the Destabilizing Effect of Damping in Nonconservative Elastic Systems," authored by G. Herrmann and I. C. Jong, and is in press in the Journal of Applied Mechanics. The second report, again under the authorship of G. Herrmann and I. C. Jong, is entitled "On Nonconservative Stability Problems of Elastic Systems with Slight Damping," and may be summarized as follows:

A linear two-degree-of-freedom system with slight viscous damping and subjected to nonconservative loading is analyzed with the aim of studying the effects of damping on stability of equilibrium. It is found that in such systems multiple ranges of stability and instability may exist in a richer variety than in corresponding systems without damping. Further, for certain systems, instability either by divergence (static buckling) or by flutter may occur first as the compressive load increases, depending upon the ratio of the damping coefficients in the two degrees of freedom. It is shown finally that systems exist for which the destabilizing effect of slight viscous damping cannot be completely removed whatever the ratio of the (positive) damping coefficients.

In addition to the above, two more analytical studies were also completed. The first report is entitled "Torsional Instability of Cantilevered Bars Subjected to Nonconservative Loading," authored by S. Nemat-Nasser and G. Herrmann, and was submitted for publication in the Journal of Applied Mechanics. This report may be summarized as follows:

A cantilevered bar of uniform cross-section and subjected at the free end to distributed, nonconservative, compressive loads is considered. It is shown that for certain cross-sections stability may be lost by either torsional divergence (torsional buckling) or torsional flutter, depending upon the load distribution

at the end section. In addition, transverse flutter can also occur. It is also indicated how such systems may be realized by means of pipes conveying fluid.

The second report, again under the authorship of S. Nemat-Nasser and G. Herrmann, can be summarized as follows:

A sufficiency theorem for the stability of a linearly viscoelastic solid subjected to partial follower surface tractions is established. It is shown that an appropriately defined functional metric space must be introduced in order to formulate a well-posed problem. The usual energy method, if applicable, and the Galerkin method, if convergent, yield stability conditions only in a functional space whose metric is defined in an average sense.

This latter study, entitled "On the Stability of Equilibrium of Continuous Systems," was not, as yet, submitted for publication.

Other analytical studies which are currently in progress include

a) Establishing a rigorous proof that the critical load of an undamped system with  $N$  degrees of freedom, subjected to nonconservative forces which are linear functions of generalized coordinates, is an upper bound for the critical load of the same system when, in addition, some sufficiently small forces which are linear functions of generalized velocities are also present. This study is almost completed, and several theorems regarding the destabilizing effect of all sufficiently small, velocity dependent forces are already established.

b) In the report which was entitled "Torsional Instability of Cantilevered Bars Subjected to Nonconservative Loading," it was indicated how such systems may be realized by means of pipes conveying fluid. However, no detailed analytical solution for this case was given. This problem is now under extensive study and the attention

is being focussed on the possibility of the existence of destabilizing effect due to Coriolis forces.

An approximate solution, based on the Galerkin method, is also being sought in order to test the applicability of such technique to nonconservative, continuous systems which admit multiple regions of stability and instability.

c) A model of two articulated rigid pipes, conveying fluid, is now constructed for experimental study. A nozzle at the end permits realization of an adjustable effective thrust, which is always tangent to the nozzle axis, and thus, supplies a follower force, and two strings which are attached to the free end and are symmetrically placed about the undeformed axis of the system provides an Euler type loading. With this model, multiple regions of stability and instability can be effectively realized. This model is now ready for quantitative measurements which are intended to test the validity and limitations of the theory.

d) A second model, which is now being constructed, consists of two articulated rigid rods with a rigid plate attached to the free end. The free end will be subjected to an air jet through a fixed nozzle which will be placed uniaxially with the undeformed axis of the system. It is believed that when a screen is attached to the end plate the system will flutter while, when the end plate is directly subjected to the air jet, it will only buckle.